Late Alluvial Fan Formation in Margaritifer Terra

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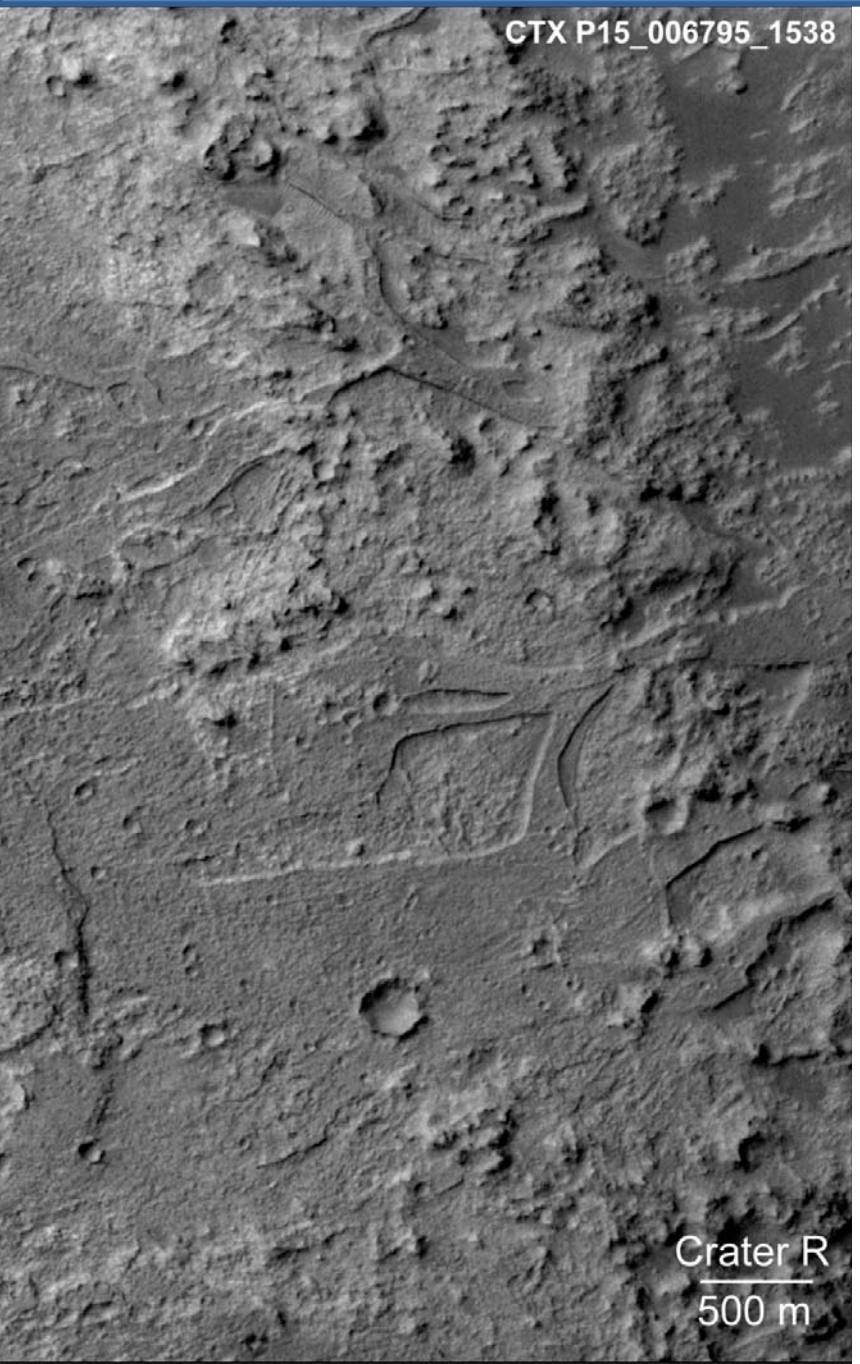
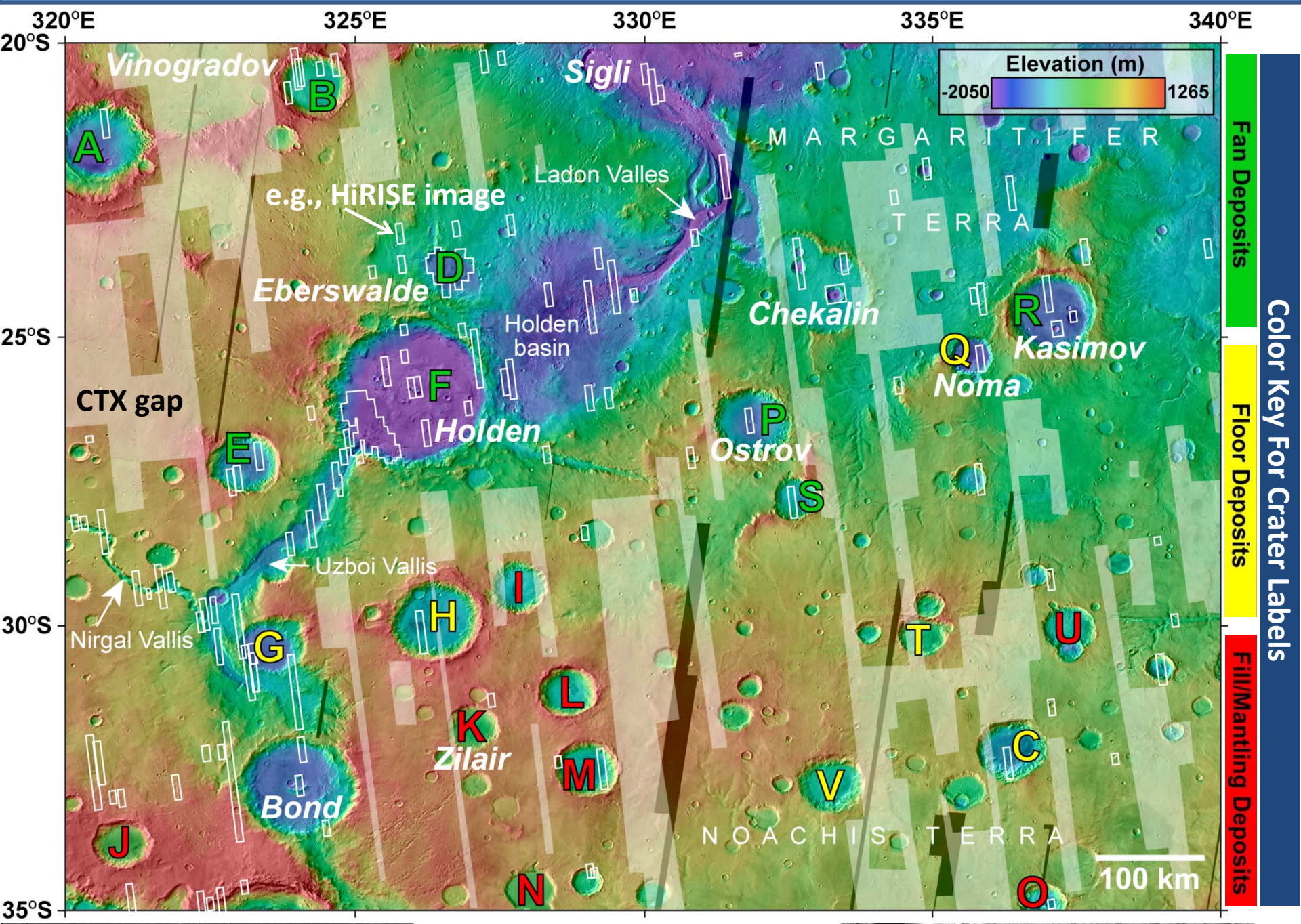
Grant, J. A. and S. A. Wilson, Late alluvial fan formation in southern Margaritifer Terra, Mars (2011), GRL, doi:10.1029/2011GL046844.

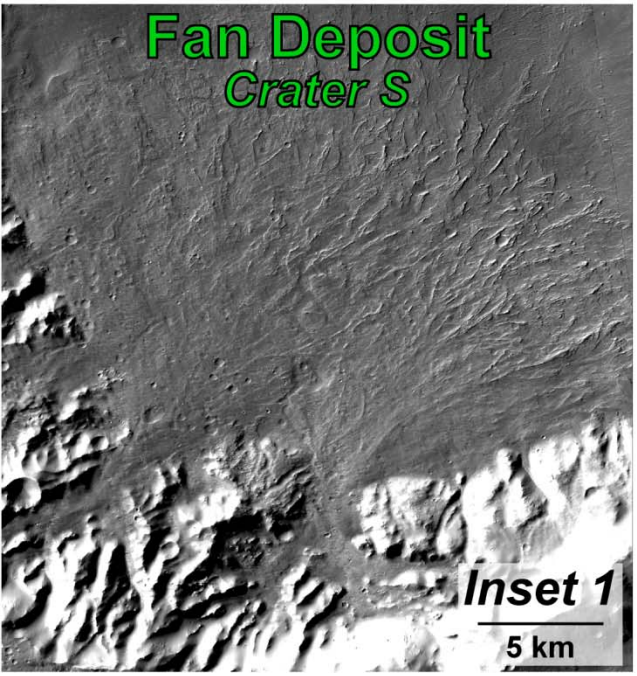


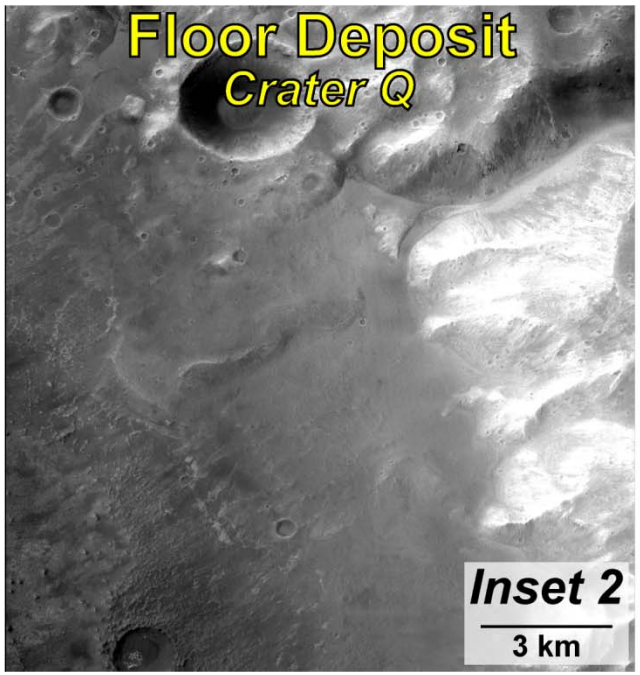
Introduction

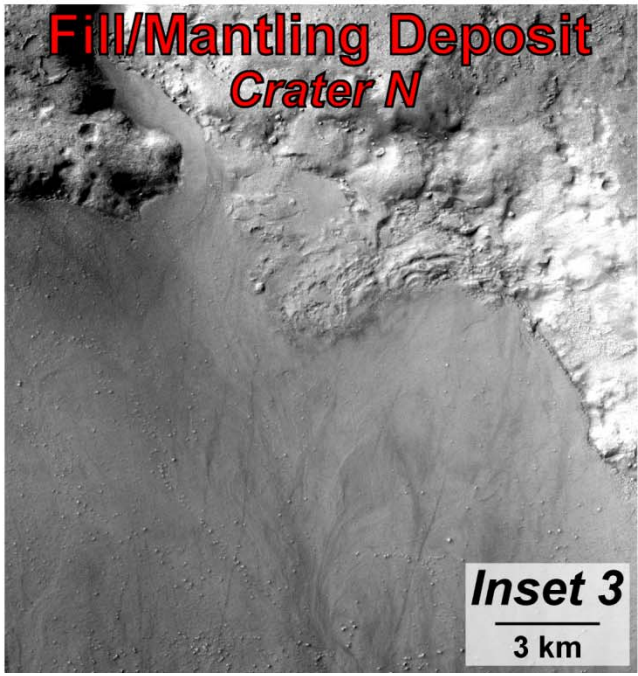
- Numerous fans identified on Mars [e.g., *Moore and Howard*, 2005; *Kraal et al*., 2008]
- How old are the fans?
  - Often assumed to be late Noachian, bound by age of their host crater
  - *Moore and Howard* [2005] crater statistics using VIS images yielded Mid-Hesperian age (uncertainty: Noachian-Hesperian boundary to mid Amazonian)
- CTX resolution and coverage allows better crater statistics
- Age and morphology provides insight into climate record


320°E
325°E
330°E
335°E
340°E
20°S
25°S
30°S
35°S
Elevation (m)
-2050
1265
Vinogradov
Sigli
MARGARITIFER
TERRA
Ladon Valles
e.g., HiRISE image
Eberswalde
Holden basin
Holden
Chekalin
Kasimov
Noma
Ostrov
CTX gap
Uzboi Vallis
Nirgal Vallis
Zilair
Bond
NOACHIS TERRA
100 km
A
B
C
D
E
F
G
H
I
J
K
L
M
N
O
P
Q
R
S
T
U
V
Fan Deposits
Floor Deposits
Fill/Mantling Deposits
Color Key For Crater Labels

Classification of Deposits



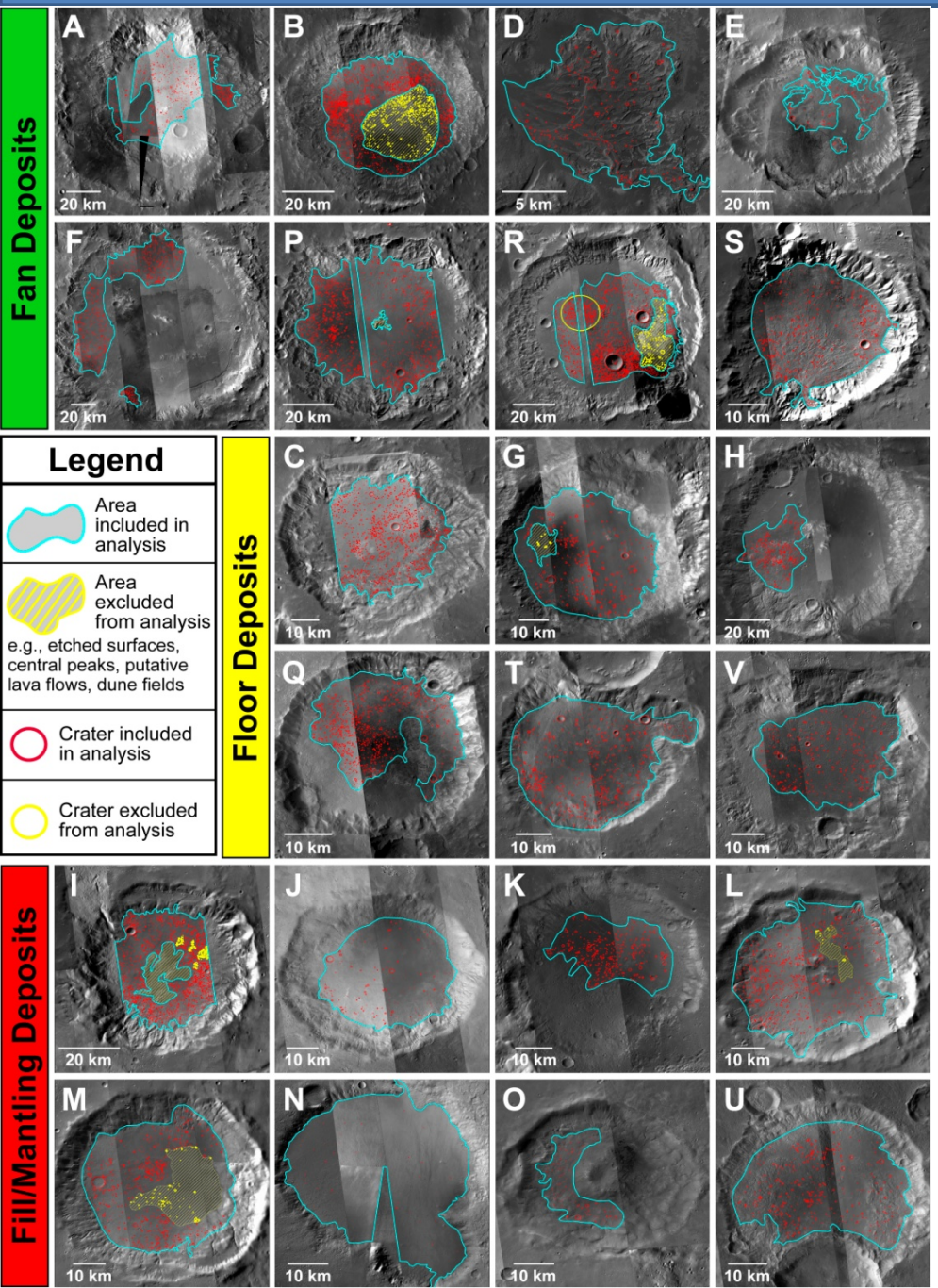




FAN DEPSOITS
- 8 craters
- Well-preserved fans with channels and lobes
- Well-developed alcoves and incised walls
- Some “playa-like” surfaces in center

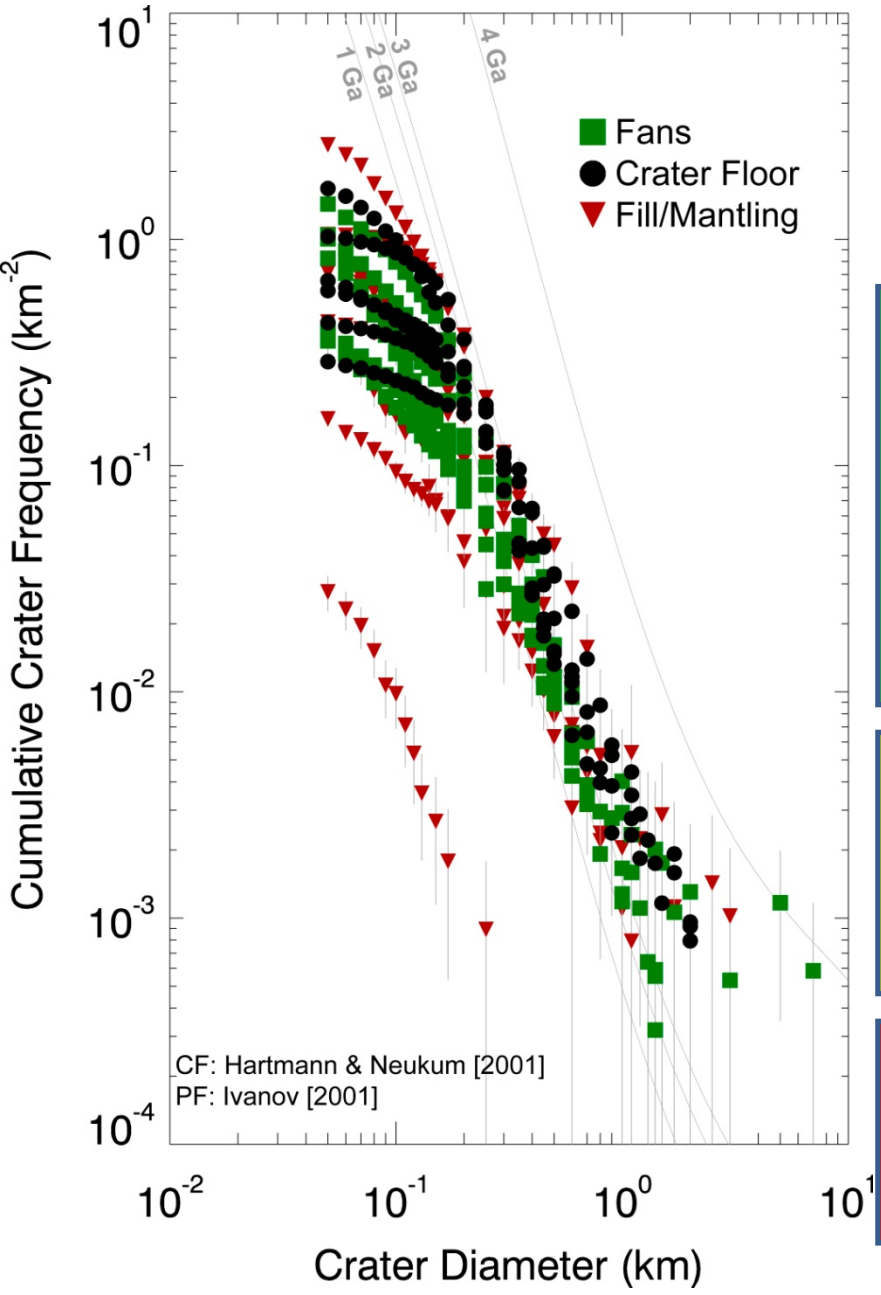
FLOOR DEPOSITS
- 6 craters
- No fans
- Light-toned layers, scabby
- Playa/shallow lacustrine environment
- Lack well-developed alcoves

FILL/MANTLING DEPOSITS
- 8 craters
- Filled with volcanic (?) or mantling material
- Possibly burying evidence for fans or floor deposits



Methods

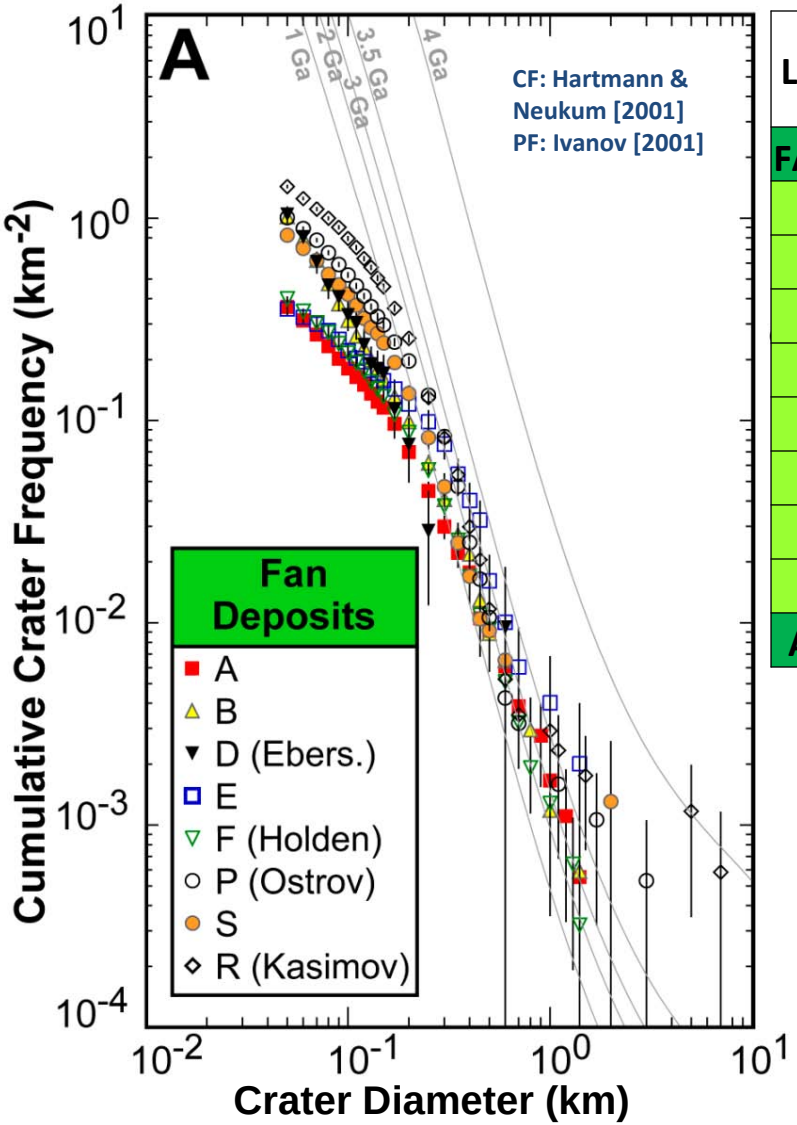
- Analyzed 22 craters (D > 50km, labeled on regional map)
- GIS Mapping and Crater Counts
  - HiRISE, CTX and global THEMIS mosaic
  - CTX data for crater counts
  - Crater Tools [*Kneissl et al.*, in press] to define areas and craters
  - Excluded gaps in CTX coverage, stripped/knobby surfaces, dune fields, central peaks, putative lava flows, obvious secondary clusters
- Crater Analysis
  - Included craters >50 m in diameter
  - Cumulative Plot
    - Craterstats [*Michael & Neukum*, 2010]
    - Chronology function from *Hartmann and Neukum* [2001]
    - Production function from *Ivanov* [2001]
  - Incremental Plot
    - Hartmann [2005]



Results: Grouped by Class

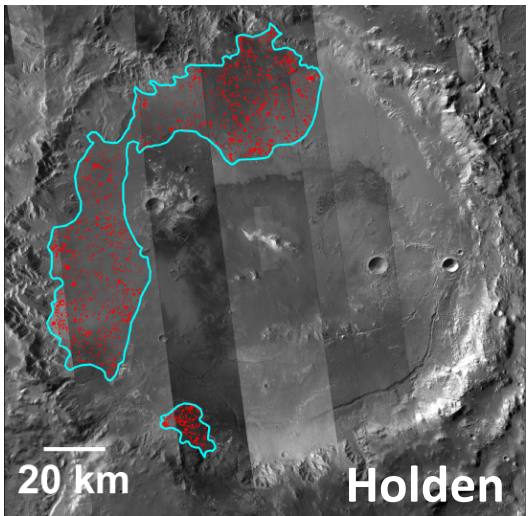
- **Fan Deposits (Holden fans and Eberswalde delta):**
  - Amazonian to Amazonian-Hesperian boundary (1.9 Ga ±0.5)
- **Crater Floor Deposits:**
  - Likely Hesperian (2.9 Ga ± 0.6)
- **Fill/Mantling Deposits**
  - Amazonian (1.8 Ga ± 0.9)

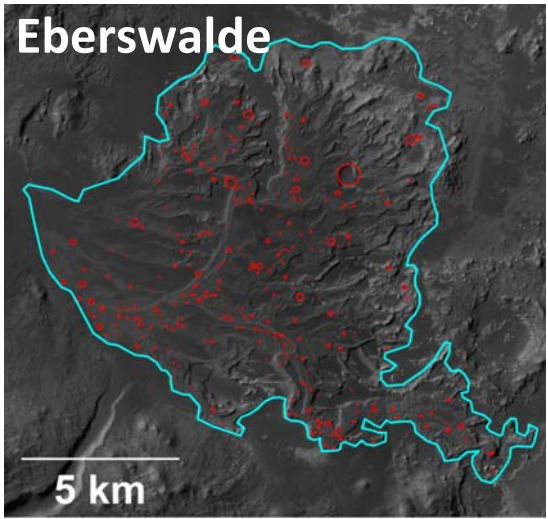
Results: Fan Deposits



Label	Name	Area km²	# craters D>50m	Diam (km)	Relative Age	Age* Ga
FAN DEPOSITS						
A		1087	637	0.2-1.5	Amaz/Hesp	2.5
B		1116	1850	0.25-1	Amazonian	2.0
D	**Eberswalde**	**105**	**104**	**0.3-0.5**	**Amazonian**	**1.0**
E		497	171	0.25-1	Amaz/Hesp	2.5
F	**Holden**	**3126**	**1207**	**0.25-1.5**	**Amazonian**	**1.5-2**
P	Ostrov	1885	1848	0.2-1	Amazonian	2.0-2.5
S		766	604	0.2-1.5	Amazonian	2.0
R	Kasimov	1711	2367	0.2-1.5	Amazonian	1.5
AVG		**1376**	**1099**		**Amazonian**	**1.9 ± 0.5**

*Best-fit age from cumulative plot based on diameter range

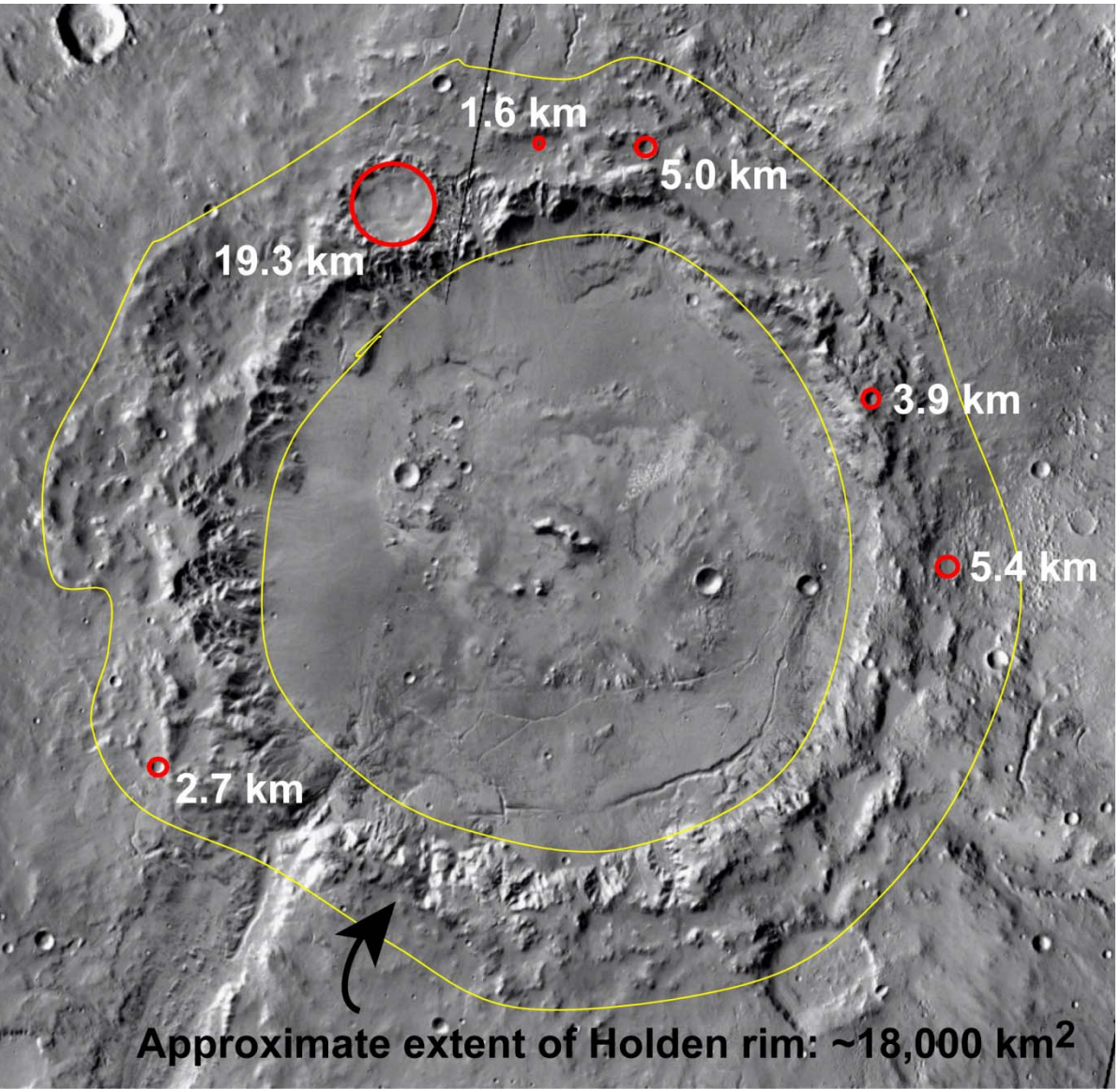




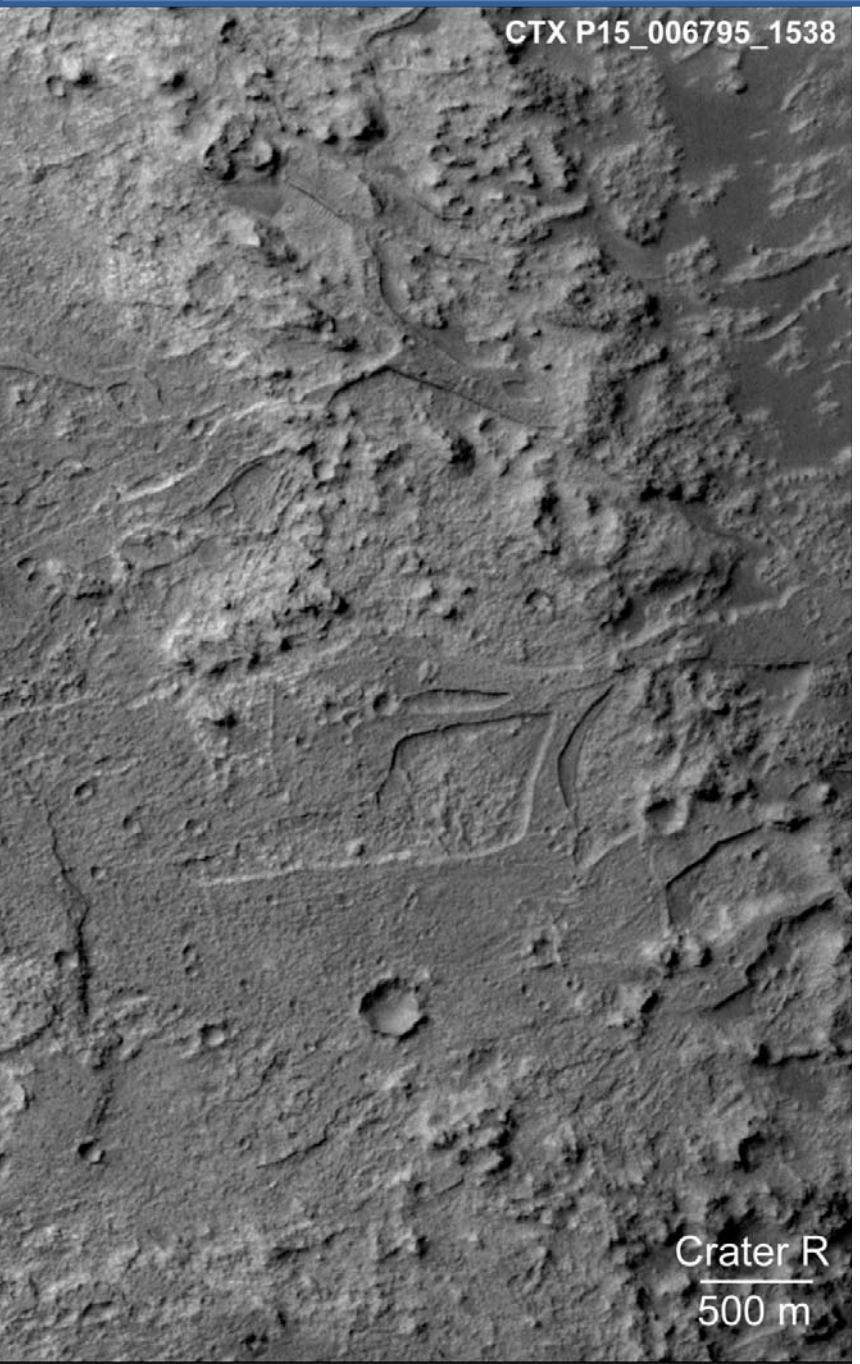
Discussion

- Despite variations in individual counts, small areas and small craters, **cluster of results within each class indicate distinct differences in ages**
- Young age of fans is consistent with regional geology:
  - Eberswalde *crater* pre-dates Holden impact [e.g. *Moore and Howard*, 2003]
  - Holden crater is likely Late Hesperian [e.g., *Irwin and Grant*, USGS map in press]
  - Eberswalde *delta* formed after Holden impact (modifies Holden ejecta) [*Moore et al*., 2003, *Irwin and Grant*, USGS map in press, *Mangold*, 4th MSL, 2010]
  - ***Therefore, Eberswalde delta and fans in Holden are likely Late Hesperian or younger → consistent with crater counts and excellent preservation of deposits***
    - ***These are not your grandmother's fans!***

More Evidence from Holden's Rim



- At least 6 craters on rim are degraded (incised rims, valleys, no ejecta)
- Need gap in time after Holden impact (late Hesperian) to allow craters to accumulate on rim before fluvial activity begins → further support for young fans (Amazonian to Amazonian-Hesperian boundary in age)



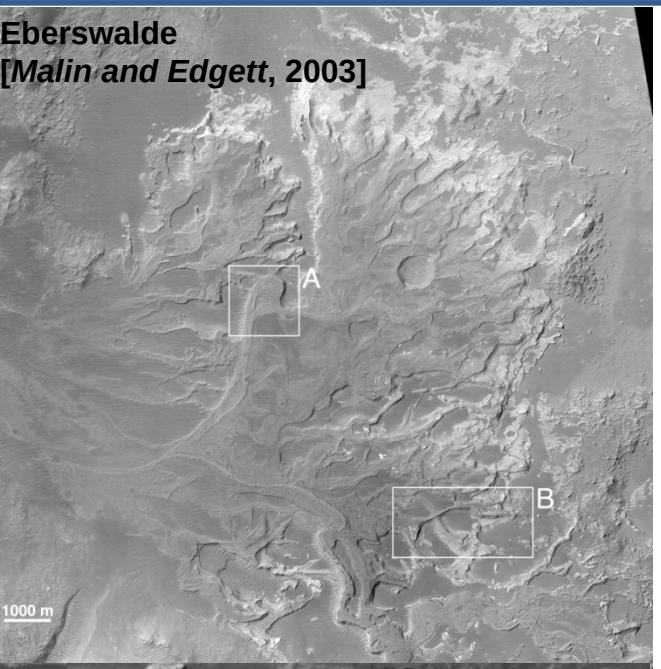
Sources of Water: Local Events

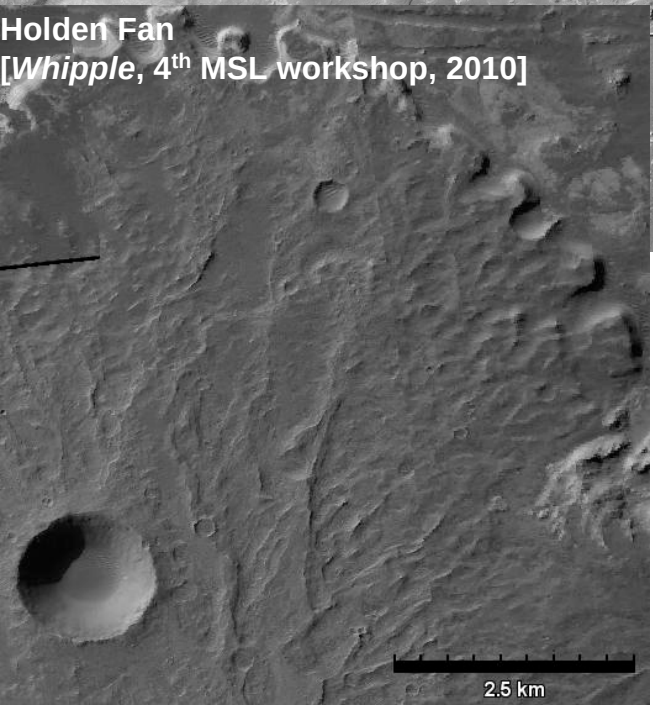
- Impact-generated runoff
  - Melting of sub-surface ice
  - Snow melting on hot ejecta
- Hale: Source for volatiles?
  - Hale located south of study area
  - Crater Hale: Early to mid Amazonian [*Jones et al.*, 2010] to Amaz-Hesperian boundary [*Cabrol et al.*, 2001]
- Hale not likely source:
  - Some fans 700-800 km away
  - Little/no correlation between Hale and azimuth of fan-bearing craters
  - Closest craters to Hale are filled/mantled

Sources of Water:

Regional/Global Scale Evidence

- Synoptic precipitation (rain or snow), enhanced by orbital variations and topography
- Contemporary geomorphic evidence:
  - Other fans on Mars [*Howard and Moore,* 2005]
  - Valleys on volcanoes [*Gulick and Baker*, 1990; *Fassett and Head*, 2008]
  - Supraglacial and proglacial valleys [*Fassett et al*., 2010]
  - Late geomorphic activity in Electris [*Grant and Schultz*, 1990]
  - A-H aged valleys in Newton and Gorgonum [*Howard & Moore*, 2011]

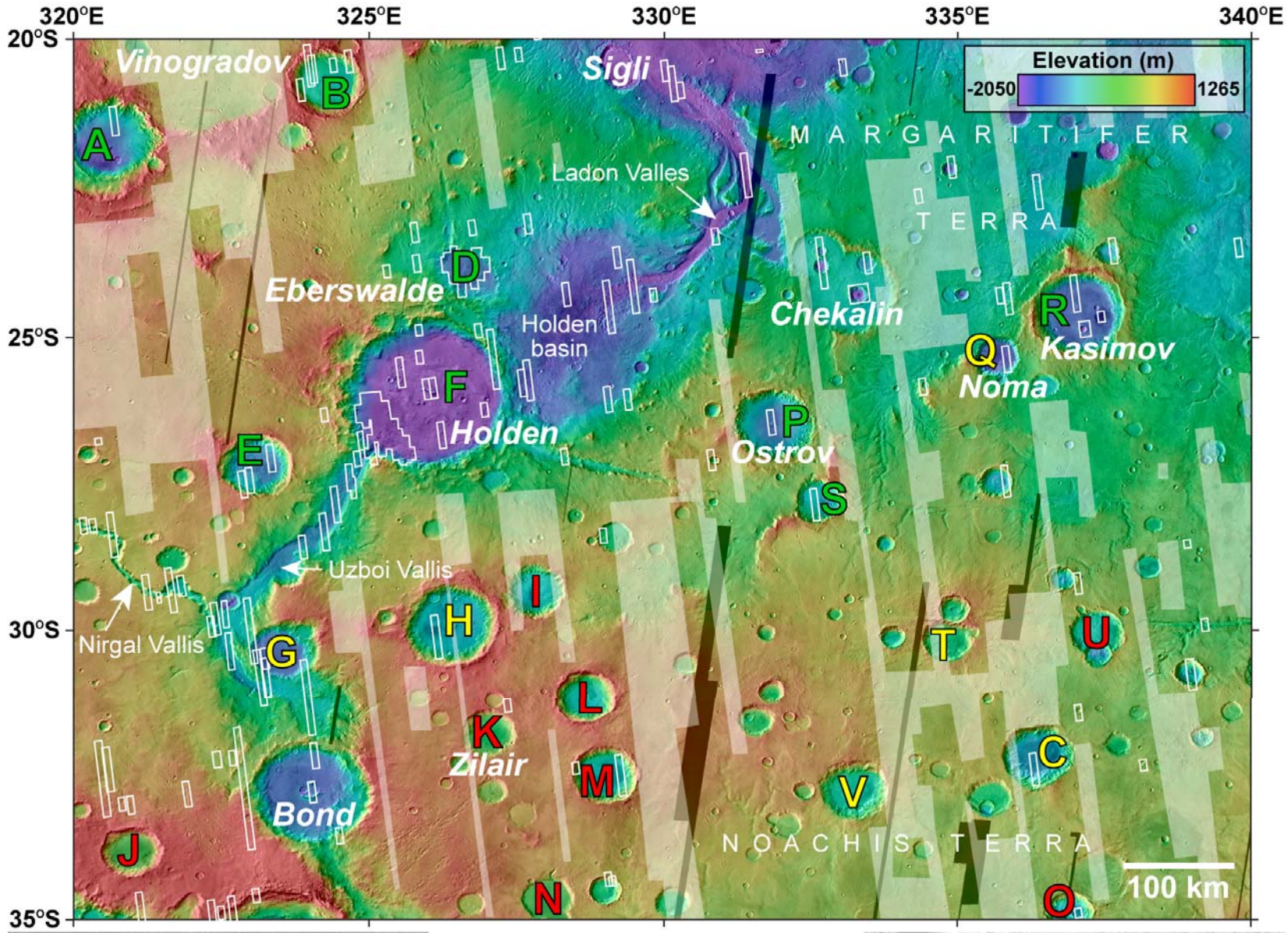




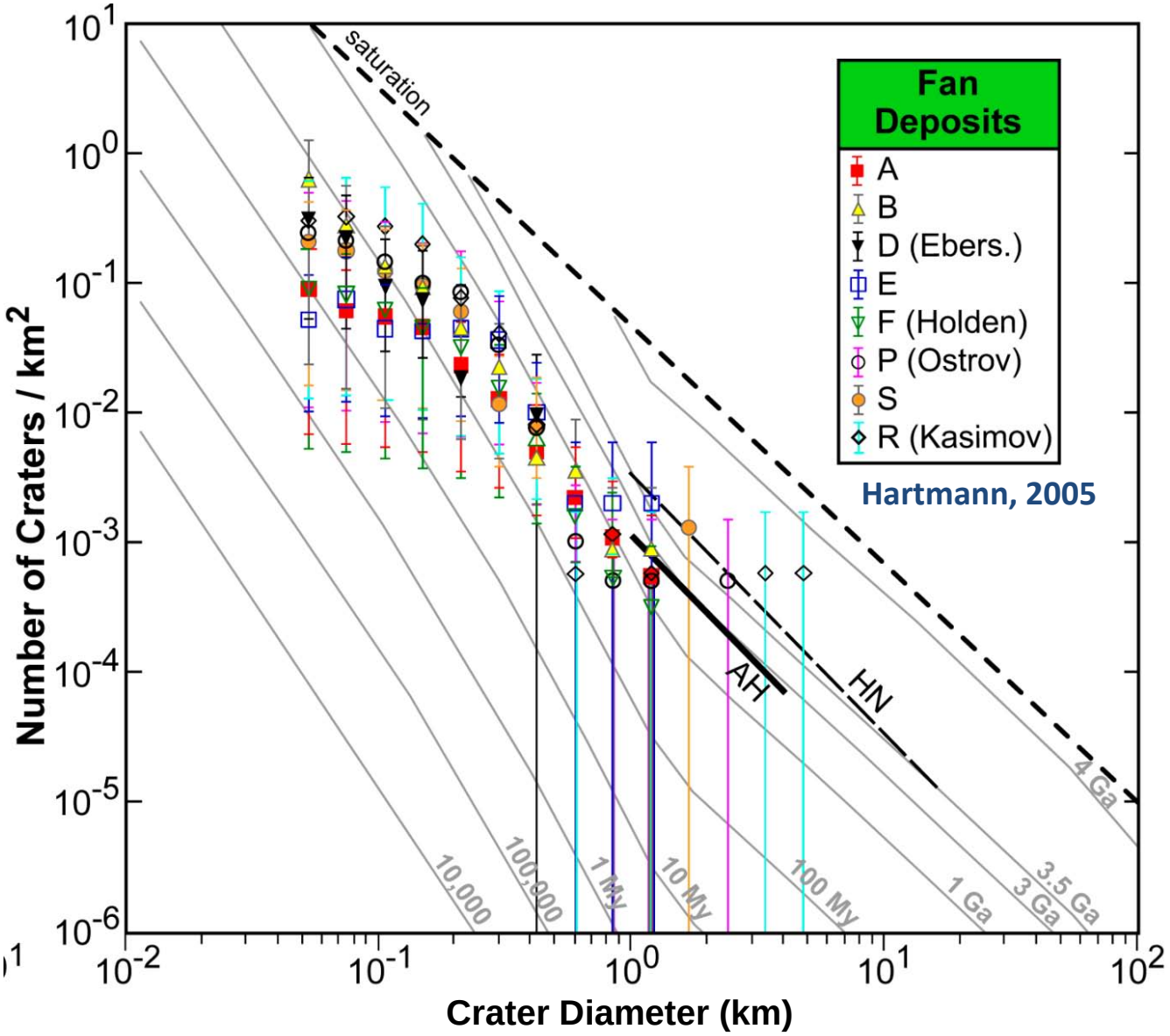
Implications for MSL

- Climate: Late, short-lived period of widespread water-driven degradation
- Access young sediment from well-preserved deposits associated with a period of **abundant liquid water**
- Hydrology, paleoclimate, evolution of atmosphere, water source, duration of sediment transport
- Understand similar fans that occur elsewhere within latitudinal band
- Assess habitability (higher preservation potential?)
- At Eberswalde: Study Holden ejecta containing older basin materials
- No clay to sulfate transition

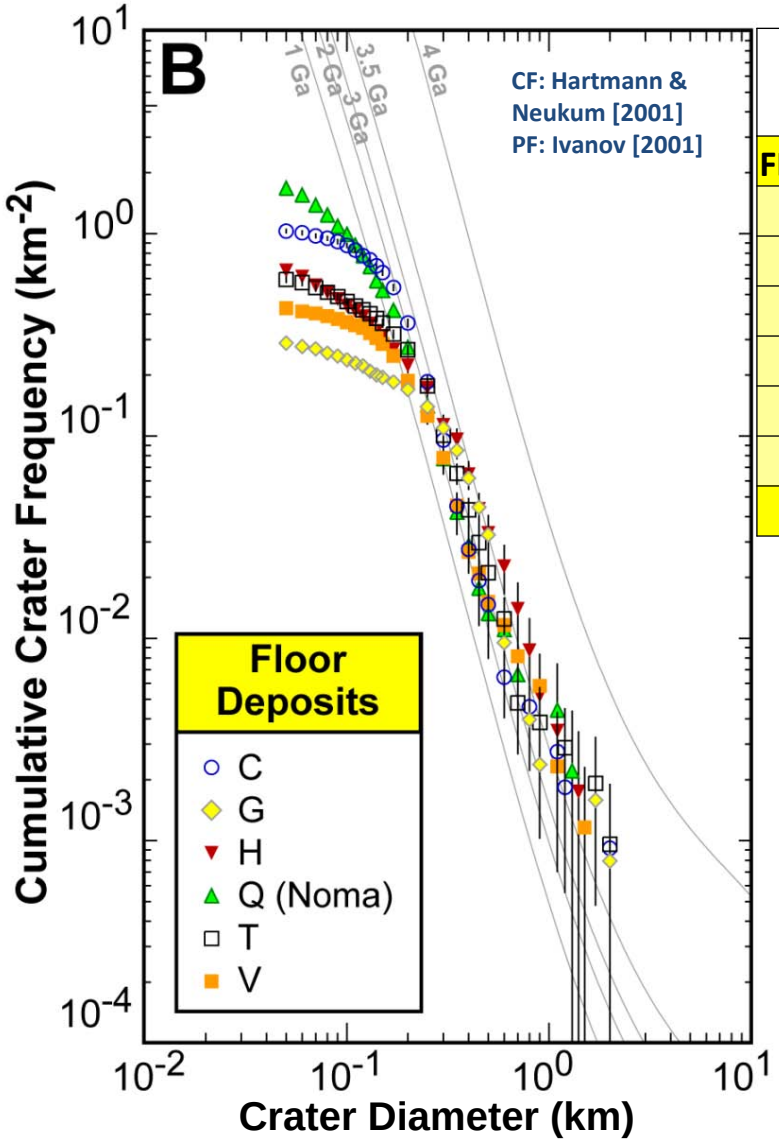
Extra Slides



Results: Fan Deposits



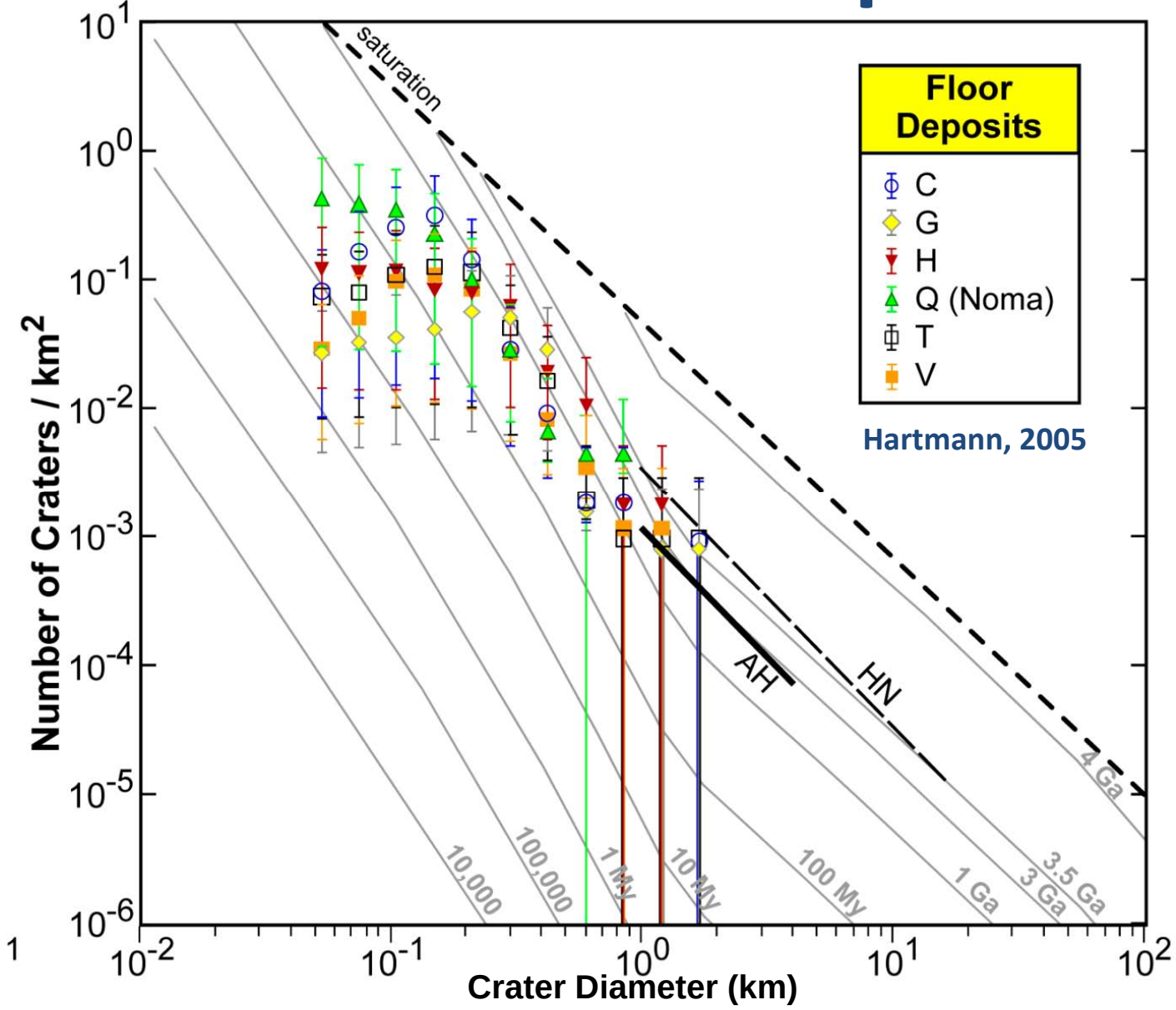
Results: Floor Deposits



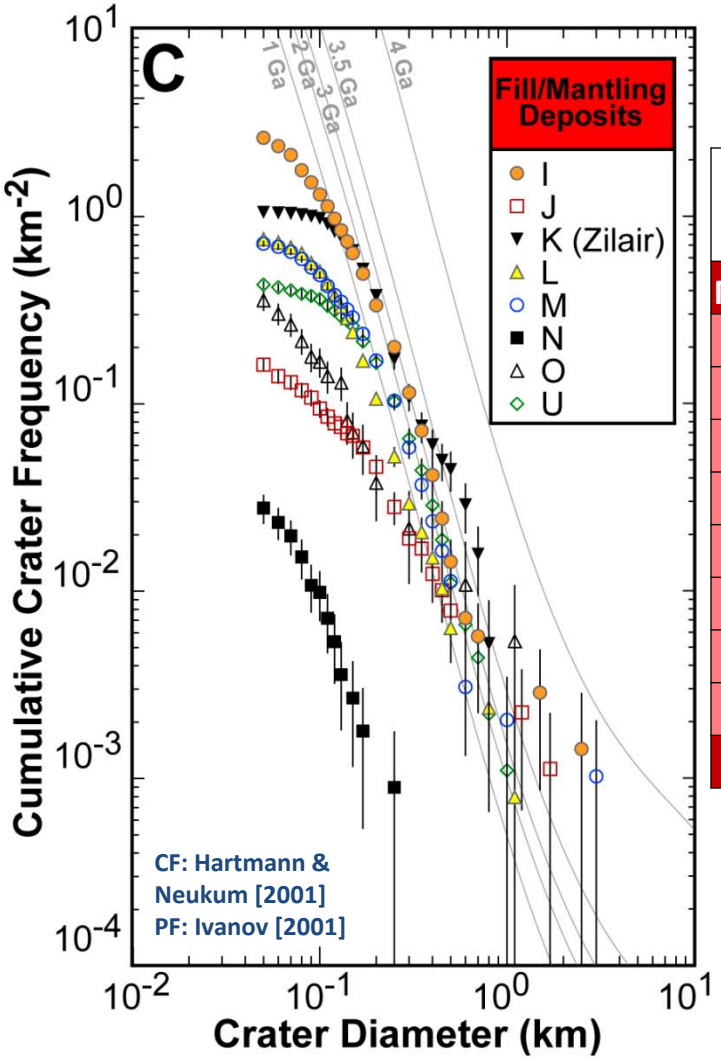
Crater Label (Name)	Area	# craters	Diam Range	Relative Age	Age*
	km²	D>50m	km		Ga
FLOOR DEPOSITS					
C	1089	1117	0.2-1	Amaz/Hesp	2.5
G	1260	359	0.3-1.5	Hesperian	3.4
H	573	369	0.3-1	Hesperian	3.5
Q (Noma)	452	749	0.25-0.6	Amazonian	2.0
T	1042	609	0.25-1	Hesperian	3.0
V	859	366	0.2-1	Amaz/Hesp	2.0-2.5
AVG	**879**	**595**		**Hesperian**	**2.9 ± SD 0.6**

*From cumulative plot based on stated diameter range

Results: Floor Deposits



Results: Fill/Mantling Deposits



Crater Label (Name)	Area km²	# craters D>50m	Diam Range km	Relative Age	Age* Ga
MANTLING/FILL					
I	700	1783	0.2-1	Amaz/Hesp	2.7
J	894	140	0.3-1	Amazonian	<1.5
K	382	400	0.2-0.9	Hesp/Noachian	3.5
L	1211	942	0.2-1	Amazonian	1.0
M	979	695	0.2-0.8	Amazonian	1.5-2
N	1122	31	0.05-0.2	Amazonian	<1
O	186	63	0.2-0.5	Amazonian	<1
U	910	390	0.25-1	Amazonian	2.0
AVG	**798**	**556**		**Amazonian**	**1.8 ± 0.9**

*From cumulative plot based on stated diameter range

Results: Fill/Mantling Deposits